PhD Position

Quantum Simulations with laser-trapped Circular Rydberg atoms

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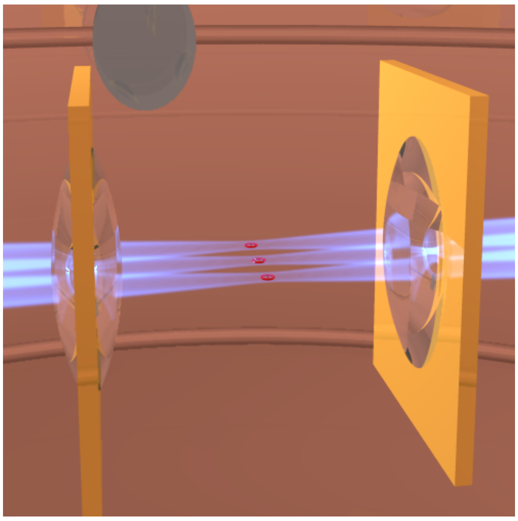
Funding: **YES**

Scientific context:

The dynamics of a quantum system, particularly in condensed matter, can be utterly complex, due to the huge size of its Hilbert space. **Quantum simulation** aims at emulating this dynamics with a simpler system, of which all parameters are under control and on which all relevant observables can be measured. Quantum simulation is the focus of an intense activity, particularly with cold atoms or trapped ions. We propose to explore an alternate, promising route, based on cold atomic ensembles in **highly excited Rydberg levels**, strongly coupled by van der Waals dipole-dipole interaction. The final goal is to realize a vacancy-free chain of high-angular-momentum (circular) Rydberg atoms trapped in an array of optical tweezers. Existing "Rydberg" quantum simulators operate with shorter-lived untrapped Rydberg atoms, This work will thus enable unprecedented capabilities for a Rydberg-atom quantum simulator, with the observation of the dynamics of the system over many interaction cycles. Studies of thermalization of quantum systems will be within reach.



Circular Rydberg atoms are trapped in an array of blue-detuned optical tweezers, inside a cryostat.

PhD Thesis:

During the PhD work, **the proposed quantum simulator will be realized and operated**. We will first realize a lattice of red-detuned optical tweezers for (high-field seeking) ground-state atoms with deterministic preparation of various geometries. We will then demonstrate the 3D laser trapping of circular Rydberg atoms inside this lattice, modified to trap the low-field seeking Rydberg atoms. Once the Rydberg atoms are laser-trapped, we will fully characterize the quantum simulator. In particular we will show the **full tunability** of the simulated condensed-matter Hamiltonian. This will pave the way towards the **realization of first quantum simulations with laser-trapped circular Rydberg atoms**, which constitutes the main objective of the PhD work.

Reference: T. L. Nguyen *et al.*, PRX 8, 011032 (2018)